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1    **The identification of potential behavioural indicators of pain in periparturient sows**

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## Abstract

Periparturient pain is a welfare concern and could contribute to piglet losses. This has led to studies investigating post-farrowing analgesia. A clear reduction in pain has not been demonstrated, partly due to a lack of pain indicators. This study quantified behaviours as potential pain indicators (PPIIn) in sows: i) before, during and after farrowing, and ii) two minutes before and after piglet births. Twenty-five sows were observed during and after, and ten pre-farrowing. Behaviour recorded included: 1) back leg forward (back leg pulled forward and/or in); 2) tremble (movement as if shivering); 3) back arch (leg(s) stretch forming an arched back); 4) paw (leg scraped in pawing motion); and 5) tail flick (tail moved rapidly up and down). Behaviours were analysed using generalized linear models and Spearman's rank correlations. All PPIIn were rare or absent pre-farrowing, highest during farrowing, and back leg forward, tremble and back arch were greater in the early post-farrowing period. Several significant positive correlations between PPIIn during and post farrowing were found. Back arch, tail flick and paw were higher before than after a piglet birth, and were more frequent earlier in the birth order. Back leg forward and tremble did not differ before and after births, and tremble increased with birth order. These behaviours, which were absent or rare pre-farrowing, present during farrowing and were lower afterwards, and showed consistent individual variation, may be quantitatively associated with pain. Spontaneous behaviours could be used to test the efficacy of analgesics or identify sows that may benefit.

*Keywords:* Behavior; Farrowing; Pain assessment; Sow; Welfare

## 1. Introduction

A key component of farm animal welfare, where possible, is freedom from pain, injury or disease (FAWC, 1979), yet farm animals may experience pain during their lifetime. For breeding females, this includes parturition, which in the life of human females is often the most painful event ever experienced, as 60% of primiparous and 45% of multiparous women report severe or extremely severe pain (Melzack, 1984). Scientists studying pain in non-

human animals can only assume that pain is likely to be present due to the presence of anatomical structures and physiological processes associated with pain, the fact that animals respond to noxious stimuli by avoidance and to minimise damage, sometimes involving complex behavioural responses, and that analgesics modify the response to stimuli thought to cause pain (Bateson, 1991; Sneddon et al., 2014)

Previous studies on stress and pain at parturition in pigs indicate pain is likely to be present (reviewd by: Mainau and Manteca, 2011). A rise in the stress hormone cortisol (Gilbert et al., 1996; Jarvis et al., 1998; Jarvis et al., 1999) and an increase in the endogenous opioid  $\beta$ -endorphin are present at parturition (Jarvis et al., 1999b, 1998). These increases took place in different farrowing environments and with the use of an opioid antagonist, indicating that parturition is likely to be stressful and painful in itself. In addition, an opioid-mediated increase in nociceptive threshold in response to a noxious thermal stimulus was present in late gestation and at parturition, providing evidence for an endogenous defence against parturition pain (Jarvis et al., 1997). More recent studies have shown the provision of non-steroidal anti-inflammatory drugs (NSAIDs) post farrowing produce some improvements to sow health, welfare and productivity (Homedes et al., 2014; Mainau et al., 2012; Sabaté et al., 2012; Viitasaari et al., 2014, 2013). For instance, differences in sow posture and activity levels with the post farrowing administration of NSAIDs have been shown. Sows treated with meloxicam spent less time lying on the third day following parturition (Mainau et al., 2012) and younger sows (parity 2 – 3) treated with the ketoprofen were more active post farrowing than younger sows given a placebo (Viitasaari et al., 2014). However, standing behaviour was not altered with meloxicam treatment in another study (Tenbergen et al., 2014). More detailed behaviours may be better indicators of pain in assessing the efficacy of post-farrowing NSAIDs. Post-farrowing NSAIDs also produce benefits for piglet welfare and performance. Piglet mortality was reduced in sows given ketoprofen (Homedes et al., 2014) and on a farm with a high incidence of post-partum dysgalactia syndrome (Sabaté et al., 2012). Meloxicam increased

average daily gain (ADG) of low birthweight piglets (Mainau et al., 2012), and an oral dose improved immune transfer to piglets, as well as increasing ADG and weaning weight (Mainau et al., 2016). Additionally, oral meloxicam administered to the sow, provided a therapeutic dose to piglets, which reduced indicators of pain associated with castration and tail docking (Bates et al., 2014).

The detailed measurement of spontaneous behaviour was included in a range of studies investigating pain associated with painful management procedures such as tail docking and castration in pigs (O'Connor et al., 2014). Pain specific behaviours associated with parturition were quantified in other polytocous species (rats: Catheline et al., 2006; Tong et al., 2008; mice: Mirza et al., 2013). These behaviours included inward turning of one of the hind paws, squashing the lower abdomen and legs towards the floor, asymmetrical contraction of the lower abdomen, elongation of the abdomen and legs and a humped back posture. These behaviours are likely related to pain and do not simply aiding the muscular movement of the fetus along the birth canal, as they were significantly reduced by epidural morphine administered when these behaviours were first seen, indicating the start of painful uterine contractions (Catheline et al., 2006). Spontaneous behaviours were also reduced in a dose dependent fashion with an intrathecal morphine infusion, administered one day before delivery, with all but the lowest dose showing significantly fewer behaviours than those given saline (Tong et al., 2008). In mice, pain-behaviours were also reduced in a dose-dependent manner with a systemic morphine infusion, without altering behaviour not thought to be pain-related, indicating that the behaviours were not reduced due to a sedative effect of the drug (Mirza et al., 2013). These behaviours were also associated with pain from uterine contractions as they began prior to fetal expulsion and their frequency increased with the administration of subcutaneous oxytocin, which increases the frequency and intensity of contractions (Catheline et al., 2006).

Although previous studies indicate pain is likely to be present, the severity of pain experienced around parturition in pigs and the impact on welfare and production of sows and

piglets has not been fully explored. Given that farmers and veterinarians rated normal farrowing as painful (3.8 and 4.5 out of 10 respectively) and difficult farrowing as highly painful (6.7 and 7.3 out of 10 respectively) and farmers considered 5.3 % of gilts and 3.7 % of sows to have difficulty farrowing (Ison and Rutherford, 2014; Ison et al. 2016), the study of pain at parturition in pigs deserves further investigation. To our knowledge, potential behavioural indicators of pain at parturition in the pig, like those observed in the rodent studies, have not previously been measured. Therefore the aim of this study was to construct an ethogram of behaviour seen during farrowing and to measure these: i) before, during and after farrowing, and; ii) immediately before and after individual piglet births, as potential indicators of pain. These behaviours could then be validated as behavioural indicators of pain, to assess the benefits of providing pain relief around farrowing, to recognise individuals for the targeted use of drug treatment. In addition, pain assessment measures could be used to evaluate whether pain increases with other aspects, for example, litter size, breed or with the use of exogenous oxytocin, which is frequently given to periparturient sows (Ison et al., 2016).

## **2. Materials and Methods**

Experimental procedures were undertaken in compliance with EU Directive 2010/63/EU and following approval by the Animal Welfare and Ethical Review Body (AWERB) at SRUC (Scotland's Rural College).

### ***2.1. Animals and housing***

Twenty-five home bred Large White × Landrace sows, ranging in parity from 2 to 8 (mean = 3.88), housed at the SRUC pig research farm were used in this study. Sows, housed in group pens of up to six individuals were artificially inseminated when signs of oestrous were detected and the expected farrowing date was calculated at 115 days following insemination. No more than five days before the expected farrowing date, sows were moved into conventional farrowing crates (1.8 × 0.5 m), with solid concrete flooring (1.8

× 1.5 m), a small slatted area at the back (0.5 × 0.5 m) and a water and feed trough at the front. Piglets had access to a heated creep area (1.5 × 0.65 m) in front of the water and feed trough. Sows were fed a standard pelleted lactation diet consisting of 16.4% crude protein, 6.8 % crude oils and fats, 4.0% crude fibre, 5.8% crude ash, 13.8% moisture, 0.8% calcium, 0.94% lysine, 0.25% methionine, 0.51% phosphorus and 0.22% sodium (DL66P Scotlean lactator sow pellets, ABN, Peterborough, UK) twice daily at 0745 and 1530 and had continuous access to fresh water. Individuals were fed 2.5 kg per day before farrowing, which was adjusted slightly based on body condition and increased gradually, based on appetite to up to 10 to 12 kg a day by weaning. Sow pens were mucked out daily at the morning feed when they were provided with two handfuls of fresh, long-stemmed straw, as roughage and nest building material. Additional straw was added at the afternoon feeding time to ensure sow's had access to nest building material and muck was removed in the afternoon on the days leading up to farrowing. Lights were switched on immediately before the morning feed and turned off at 1600 and an additional night-light was provided in the centre of each room of six crates.

## *2.2. Behavioural observations*

Closed-circuit television (CCTV) cameras (LL20, infra-red cameras, FR concepts, Ireland) were mounted above each farrowing crate to record behaviour using GeoVision Digital Surveillance System software (ezCCTV Ltd, Herts, UK). Digital video footage was collected and stored to be analysed later using The Observer XT 9.0 (Noldus Information Technology, Wageningen, The Netherlands). All 25 sows were observed continuously from the birth of the first to the last piglet and then for five minutes every hour for 24 hours, beginning one hour after the last piglet was born. To confirm the spontaneous behaviours were farrowing-specific, a subset of ten sows were observed continuously for five minutes every hour between 60 and 36 hours before the birth of the first piglet. This time period was chosen to be before the onset of nest building behaviour and therefore a true baseline. The ethogram of behaviours observed is presented in Table 1.

*Insert Table 1 here*

### *2.3. Data Analysis*

Behaviour data were exported from The Observer into an excel spread sheet to be statistically analysed using Genstat (14<sup>th</sup> Edition; VSN International Ltd., Hemel Hempstead, UK). Results were considered statically significant at  $P < 0.05$ . As the data were not normally distributed, generalized linear mixed models (GLMM) using the residual maximum likelihood method (REML), with a Poisson distribution and logarithm function, and Spearman's rank correlation coefficients were used to analyse the behaviour variables.

#### *2.3.1. Periparturient behaviour*

The post-farrowing observations (5 minutes per hour) were combined into four six hour blocks, for the first (Post 1), second (Post 2), third (Post 3) and fourth (Post 4) block of six hours after the birth of the last piglet. Differences between observation periods (Pre farrowing, during farrowing, Post 1, Post 2, Post 3 and Post 4) were analysed with 'observation period' as a fixed factor. Parity and the total number of piglets born were included as fixed factors. Sow ID/observation period was added into the random model to account for repeated measures. To enable behavioural variables to be compared between observation periods of different lengths, the behavioural durations were converted to % of the observations period and the frequencies as number per minute. Post-hoc analyses were conducted between the different observation periods, to analyse where the differences lie, using least significant difference (LSD) tests. Spearman's rank correlation coefficients and  $P$  values were calculated for the behaviours back leg forward, tremble, back arch and paw, between the during and post (1, 2, 3 and 4) farrowing observations.

#### *2.3.2. Pre versus post piglet expulsion*

To investigate behaviours associated with piglet expulsion, data for the two-minutes immediately before and after each individual piglet birth were exported from The Observer.



The before or after piglet expulsion data were analysed using GLMMs with ‘before or after’ and birth order as fixed factors and Sow ID in the random model. Data were analysed for the first 14 piglet births or total piglet births for sows that had fewer than 14 piglets. This resulted in a total of 306 piglet births in the analysis.

### 3. Results

Production information for the 25 sows observed in this study is shown in Table 2. The data for the Large White × Landrace sows used in this study are shown alongside average figures for the UK indoor sow herd as a whole (BPEX, 2014).

*Insert Table 2 here*

#### 3.1. Periparturient behaviour

Fig. 1 and 2 shows the behaviours as potential pain indicators (PPI<sub>n</sub>) and postures before farrowing and the onset of nest building (Pre), during farrowing from the birth of the first to the last piglet (During), then for Post 1, Post 2, Post 3 and Post 4. All PPI<sub>n</sub> differed overall by observation period (back leg forward:  $F_{5, 130} = 36.22$ ,  $P < 0.001$ , tremble:  $F_{5, 130} = 29.52$ ,  $P < 0.001$ , back arch:  $F_{5, 130} = 42.36$ ,  $P < 0.001$ , paw:  $F_{5, 130} = 12.13$ ,  $P < 0.001$ , and tail flick:  $F_{5, 130} = 28.52$ ,  $P < 0.001$ ). All PPI<sub>n</sub> were rare or absent pre farrowing (Fig. 1). The behaviours ‘back leg forward’, ‘tremble’ and ‘back arch’ were more frequent During compared with Post farrowing, and Post farrowing, they were more frequent during Post 1, compared with Post 2, Post 3 and Post 4 (Fig. 1 a) to c) respectively). Compared with back leg forward, tremble and back arch, that were highest during farrowing and post-farrowing were higher for the Post 1 observations, paw was seen more consistently during and post farrowing, but was slightly more frequent during farrowing and decreased for the Post 4 time period (Fig. 1 d). Tail flick was mainly only seen during farrowing and was infrequent in the Post 1 – 4 observations (Fig. 1 e). There were no differences by parity or total piglets born for the spontaneous behaviours measured (data not shown).

*Insert Figure 1 here*

For the postures, lie lateral, lie ventral and sit differed overall by observation period (lie lateral:  $F_{5, 130} = 5.65$ ,  $P < 0.001$ , lie ventral:  $F_{5, 130} = 3.62$ ,  $P = 0.003$ , sit:  $F_{5, 130} = 4.35$ ,  $P < 0.001$ ; Fig. 2 a), b) and d) respectively) and stand and kneel did not differ (stand:  $F_{5, 130} = 1.48$ ,  $P = 0.192$ , kneel:  $F_{5, 130} = 1.95$ ,  $P = 0.084$ ; Fig. 2 c) and e) respectively). Sows spent a high percentage of time lying lateral for all observation periods and the least time was spent kneeling (Fig. 2). The highest percentage of time spent lateral lying was during the Post 1 observation period, where sows spent less time in other postures. Although lateral lying was high during farrowing, it was more variable between individuals than in the Post 1 observations, where lateral lying was highest (Fig. 2 a). Overall, sows became more active from the Post 2 observations onwards, spending less time lateral lying and more time in other postures including ventral lying, standing, sitting and kneeling (Fig. 2). There were no differences in posture for parity or the total number of piglets born (data not shown).

*Insert figure 2 here*

Spearman's rank correlation coefficients (Table 3) show the PPI in back leg forward, tremble, back arch and paw were positively correlated for the majority of observations during and post farrowing (Post 1, 2, 3 and 4).

*Insert Table 3 here*

### *3.2. Before versus after piglet expulsion*

The two minutes immediately before and after the first 14 piglet births and the mean for the first 14 births are presented in Fig. 3. Back arch ( $F_{1,610} = 223.75$ ,  $P < 0.001$ ; fig.3 A), tail flick ( $F_{1,610} = 310.30$ ,  $P < 0.001$ ; fig.3 B), and paw ( $F_{1,610} = 9.52$ ,  $P = 0.002$ ; fig. 3 C) were more frequent immediately before compared with after a piglet birth, whereas back leg forward ( $F_{1,610} = 0.23$ ,  $P = 0.632$ ; fig.3 D) and tremble ( $F_{1,610} = 0.00$ ,  $P = 0.986$ ; fig.3 E) did not differ before and after an expulsion. For birth order, the frequency of back arch ( $F_{13,598} =$

4.90,  $P < 0.001$ ; fig.3 A), tail flick ( $F_{13,598} = 8.58$ ,  $P < 0.001$ ; fig.3 B) and paw ( $F_{13,598} = 1.80$ ,  $P = 0.040$ ; fig.3 C) differed across the first 14 piglet births. Back arch and tail flick were more frequent immediately before the first piglet birth; with tail flick becoming slightly less frequent with subsequent births and paw was more frequent earlier on in the birth order than later. Back leg forward did not differ by birth order ( $F_{13,598} = 1.42$ ,  $P = 0.144$ ; fig.3 D), whereas tremble significantly increased as birth order progressed ( $F_{13,598} = 11.12$ ,  $P < 0.001$ ; Fig. 3 E).

*Inset figure 3 here*

## **4. Discussion**

### **4.1. Periparturient behaviour**

Similarly to the studies in rodents, which identified behavioural indicators of pain around parturition (Catheline et al., 2006; Mirza et al., 2013; Tong et al., 2008), several behaviours were observed as potential pain indicators in this study. Back leg forward could be compared to the inward turning of the hind paw seen in rats during parturition (Catheline et al., 2006), back arch could also be compared to the humped-back posture (Tong et al., 2008). Behaviours similar to those described in this study were observed in relation to painful management procedures in pigs (O'Connor et al., 2014) and tail raising is suggested to be related to pain at different levels of calving difficulty in dairy cattle (Barrier et al., 2012). In the current study, potential behavioural indicators of pain were absent or rare in pre-farrowing observations, were greatest during farrowing and in the immediate post-farrowing period, when expulsion of the placenta is taking place. Potential behavioural indicators of pain remained higher than pre-farrowing values up to 24 hours after the last piglet was born, whereas postures returned to pre-farrowing levels within 24 hours. This indicates that pain is likely to persist beyond the piglet and placental expulsion phase of farrowing, which could be due to uterine involution as the uterus contracts to return to its pre-gestation size (Deussen

et al., 2011). Therefore, these behavioural indicators could be useful in assessing the benefits of post-farrowing NSAIDs.

The positive correlation between potential behavioural indicators of pain observed during and after farrowing indicates that if these behaviours are indicators of pain, sows experiencing more pain during farrowing, could experience more pain afterwards. This would make these indicators useful in the early assessment of pain associated with farrowing to provide analgesic treatment for post-farrowing inflammatory pain. In a previous study, Mainau et al., (2010) created an ease of farrowing score (EFS), based on the total duration of farrowing and inter-birth interval, sow posture and frequency of posture changes on the day before and day of farrowing, along with the presentation (anterior or posterior), viability (high or low) and sow posture at birth. This EFS correlated with four point visual assessment of the level of farrowing difficulty (from 1 = high difficulty, to 4 = easy or spontaneous farrowing), scored by farm staff, in that sows given 1 or 2 in the visual assessment had lower ease of farrowing scores than sows given 3 or 4. This approach of using multiple measures to identify deviation from normal is similar to clinical assessment scores used to identify treatment needs for animals in biomedical research (Morton and Griffiths, 1985) and could be used to assess potential post-farrowing analgesia treatment in future studies of pigs. This could combine the behavioural indicators described in the current study, along with welfare indicators measured previously (Mainau et al., 2012; Tenbergen et al., 2014; Viitasaari et al., 2014, 2013), to identify individuals that could benefit most from treatment.

#### *4.2. Before versus after piglet expulsion*

The behaviours tail flick, back arch and paw were more frequent in the two minutes before, compared with after piglet expulsion. In human females, the first stage of labour produces visceral pain from uterine contractions, distension of the lower uterine segment and cervical dilation, whereas during delivery (the second stage of labour), somatic pain dominates from pressure of the fetus on the lower uterine segment (Lowe, 2002). Visceral

pain is generally diffuse and poorly localised whereas somatic pain is sharp and well localised (Brownridge, 1995). Since tail flick was strongly associated with imminent piglet expulsion, it could be associated with localised somatic pain from pressure of the fetus on the pelvic structures surrounding the vagina. Movement involving the whole body (e.g. back arch) could be from visceral pain associated with uterine contractions. The rat study demonstrated that pain behaviours seen during parturition were increased with exogenous oxytocin, which the authors suggested could be indicating pain associated with uterine contractions (Catheline et al., 2006). The use of exogenous oxytocin, to increase the frequency and intensity of uterine contractions, could confirm the association between back arch and uterine contractions in sows.

Gilbert et al., (1994) demonstrated the pulsatile nature of oxytocin secretion, with a sharp rise, along with powerful abdominal contractions immediately before a piglet expulsion and another rise in oxytocin immediately afterwards. However, the immediate post-birth period, was described as 'maternal inertia' or rest following a piglet birth (Gilbert et al., 1994), which was also shown in the current study with a lower frequency of tail flick, back arch and paw in the post-birth period. The authors suggested this post-expulsion increase in oxytocin could be linked to uterine contractions moving further material (fetuses or placenta) along the birth canal (Gilbert et al., 1994). If these uterine contractions are painful, a behavioural response in the post-birth period would be expected, which was not the case. This could be explained by the pattern of behaviours observed at parturition in the rat study, as Catheline et al., 2006 suggested the behavioural response is related to uterine contractions of high intensity, rather than all uterine contractions. This could also be the case for pigs, as the post expulsion oxytocin surge (Gilbert et al., 1994) is associated with 'maternal inertia', whereas the pre-expulsion increase is associated with a greater behavioural response.

Tail flick was rare before and after farrowing, but was seen often during farrowing and was strongly associated with imminent birth, meaning it could be indicating the presence

of the piglet at the distal end of the birth canal. It is interesting that this behaviour, along with back arch was more frequent immediately before the first piglet birth, tail flick decreased slightly with subsequent births and paw was also more frequent earlier on in the birth order. A previous study demonstrated an increase in nociceptive threshold leading up to and during parturition, which was shown to be opioid-mediated (Jarvis et al., 1997) and endogenous opioid  $\beta$ -endorphin levels increased with subsequent piglet births during parturition (Jarvis et al., 1999). It was suggested that this could be an endogenous defence against the pain of parturition (Jarvis et al., 1997) and  $\beta$ -endorphin levels were shown to positively correlate with reported pain scores of women during labour, as well as increasing as labour progressed and decreasing with the administration of epidural analgesia (Räsänen et al., 1984). The fact that the frequency of several behaviours measured in this study decreased with subsequent births, especially following the first piglet birth, could be related to the increasing endogenous defence against the acute pain of passing piglets. Additionally, increasing distension of the birth canal may make it easier to pass piglets. Conversely, the behaviour tremble increased with subsequent piglet births, but this behaviour differed, along with back leg forward, in that it did not increase in duration immediately preceding a birth. Therefore, tremble could be indicating a cumulative effect of inflammation, pain or fatigue as parturition progresses, representing a different aspect of the experience, rather than the acute pain of passing individual piglets or intense uterine contractions. It is also possible that a general decrease in putative pain behaviour with an increasing number of piglet births could be related to fatigue, adaptation by the sow, or the increase in suckling behaviour with the presence of piglets, rather than a reduction in pain, as the expression of these behaviours could be energetically demanding.

## **5. Conclusion**

This study has characterised and quantified periparturient spontaneous behaviour as potential indicators of pain and discussed them in relation to previous studies of parturition in pigs. The longitudinal pattern of behavioural expression and association with piglet expulsion

indicates a quantitative association with pain. The behaviour back leg forward was not directly associated with individual piglet births, as was tremble, which also increased with birth order, making them the most promising behaviours to be used as indicators of inflammatory pain, to assess the benefits of post-farrowing NSAIDs. If future validation studies support their use as pain indicators, they could be simplified and incorporated into an on-farm assessment tool to indicate where the use of these drugs would be of most benefit. In addition, these behaviours could be used to test existing or new analgesic drugs in large scale on-farm studies, with the potential to improve sow welfare through the assessment and alleviation of pain. Analgesic intervention during farrowing would validate the behaviours back arch, tail flick and paw as indicators of visceral pain from uterine contractions and somatic pain from piglet expulsion and the use of oxytocin could indicate whether back arch is an indicator of uterine contractions.

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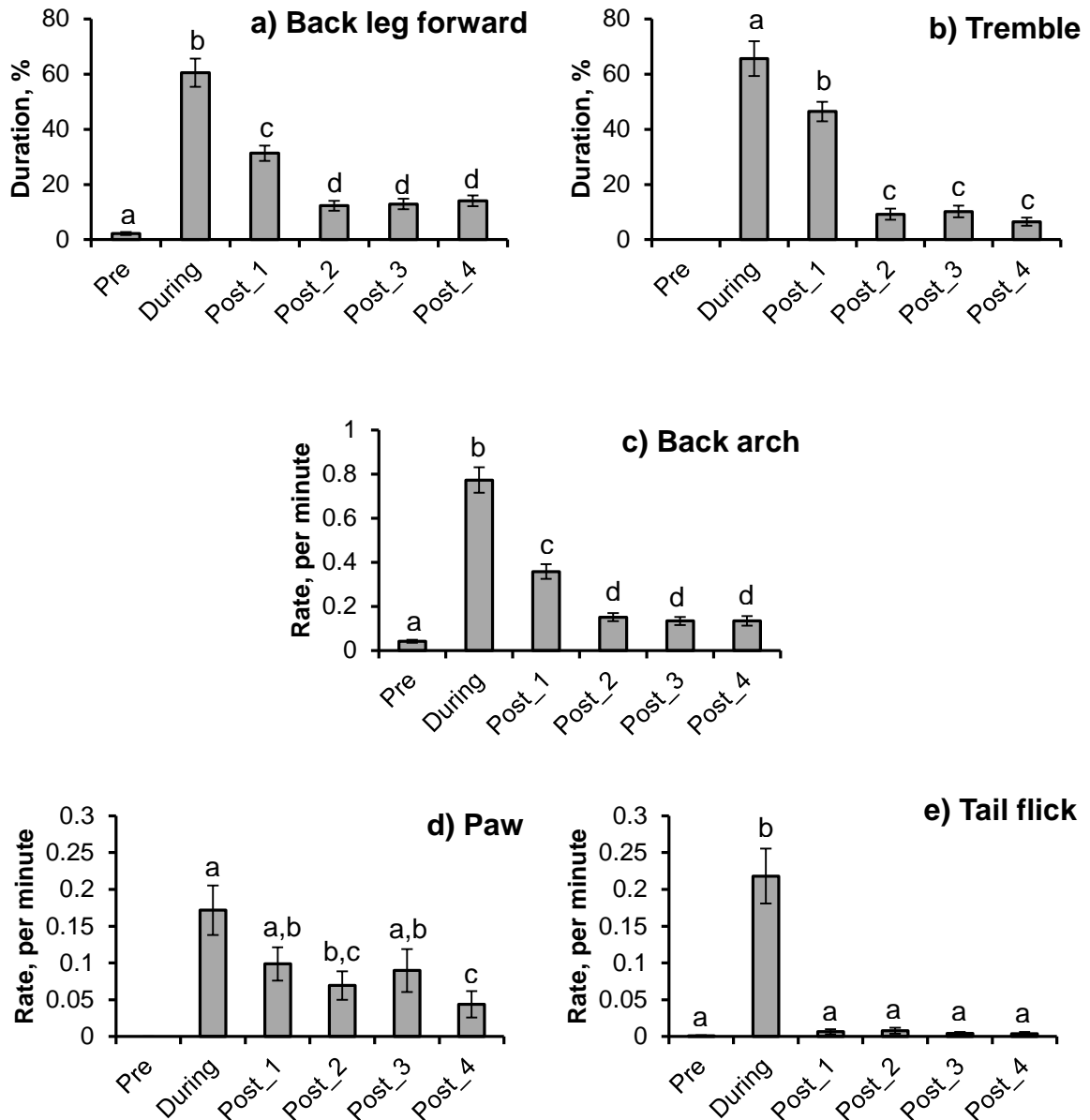
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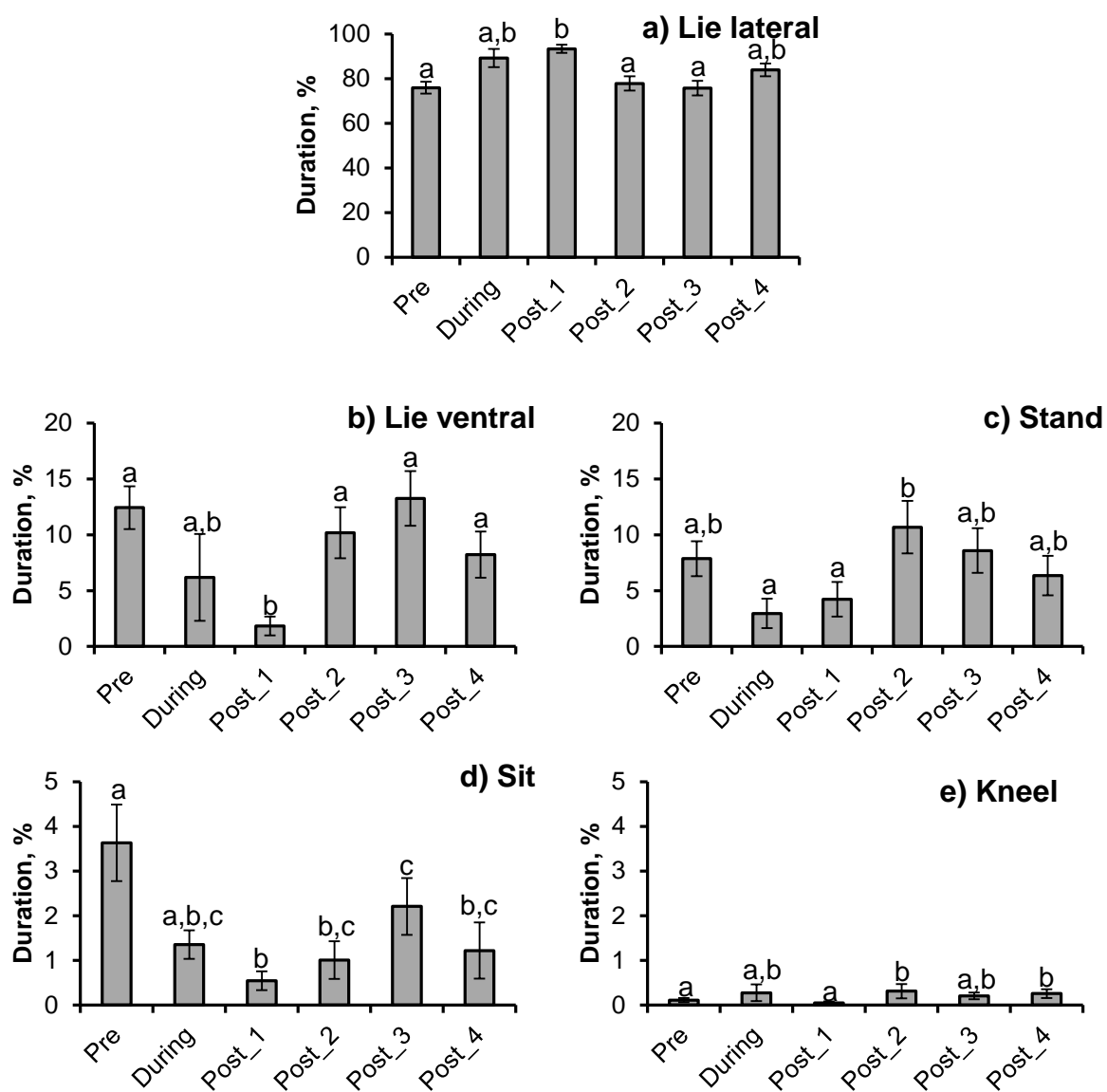
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438

**Fig.1.** Duration (%) or frequency (number per minute) (mean  $\pm$  SEM) for the behaviours: a) Back leg forward; b) Tremble; c) Back arch; d) Paw and; e) Tail flick, Pre, During and four six hour block post farrowing (Post 1, Post 2, Post 3 and Post 4). Bars with different letters show a significant difference ( $P < 0.05$ ).

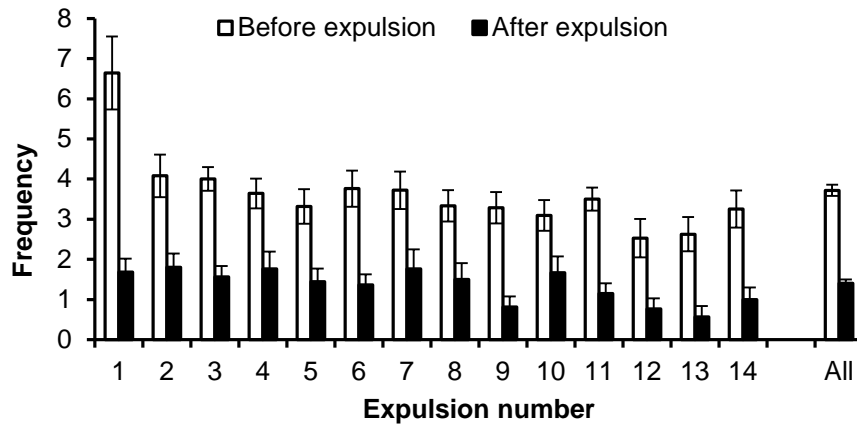


**Fig.2.** Duration (%) (mean  $\pm$  SEM) for the postures: a) Lie lateral; b) Lie ventral; c) Stand; d) Sit and; e) Kneel, Pre, During and the four six hour blocks post farrowing (Post 1, Post 2, Post 3 and Post 4). Bars with different letter show a significant difference ( $P < 0.05$ ).

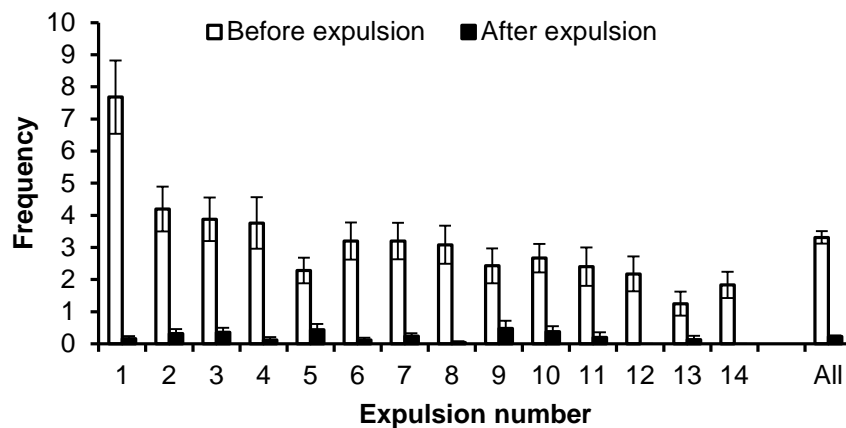


**Fig.3.** Frequency or duration (mean  $\pm$  SEM) of the behaviours: A) back arch; B) Tail flick; C) Paw; D) Back leg forward; and E) Tremble for two minutes immediately before (in white) and after (in black) a piglet birth for the first 14 births, and the mean ( $\pm$  SEM) of all 14 births.

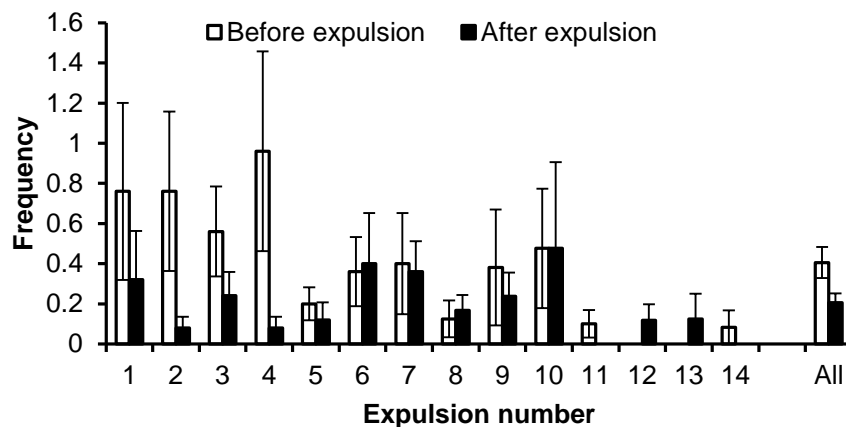
#### A) Bach arch



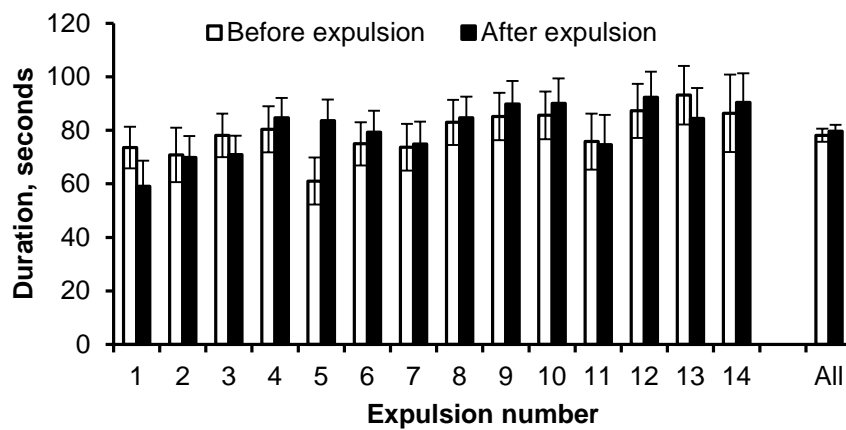
#### B) Tail flick



#### C) Paw

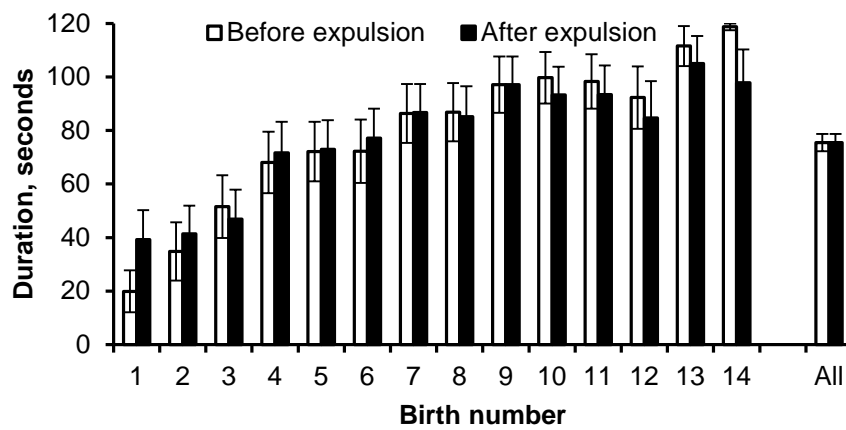


#### D) Back leg forward



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#### E) Tremble



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466

**Table 1**

Ethogram of behaviours observed during the study. Behaviours were recorded as duration in seconds (state) or frequencies (event)

Behaviour	Description	State	Event
Posture	Stand	Upright, with all feet on floor	✓
	Sit	Front legs straight and back end down on the floor	✓
	Kneel	Front knees on the floor, with back legs straight	✓
	Lie lateral	Lying on one side with udder exposed	✓
	Lie ventral	Lying with the udder on the floor	✓
Other behaviour	Tremble	Visible shaking as if shivering when in a lateral lying position	✓
	Back leg forward	In a lateral lying position, the back leg is pulled forward and/or in towards the body	✓
	Back Arch	In a lateral lying position, one or both sets of legs become tense and are pushed away from the body and/or inwards towards the centre, forming an arch in the back	✓
	Tail flick	Tail is moved rapidly up and down	✓
	Paw	In a lateral lying position, the front leg is scraped in a pawing motion	✓
	Piglet birth	A piglet is fully expelled from the sow	✓



**Table 2**

Production data for the 25 Large White × Landrace sows used in this study, along with the mean for 2013-14 within the United Kingdom (UK) (BPEX, 2014)

Production data	Minimum	Maximum	Mean ± SEM	UK mean
Total born	7	18	13.00 ± 0.62	13.16
Live born	7	17	12.72 ± 0.56	12.37
Stillborn	0	4	0.28 ± 0.17	0.72
Live born mortality, %	0	25	8.74 ± 1.64	12.33
Number weaned	8	15	11.64 ± 0.33	10.82

**Table 3**

Spearman's Rank correlation coefficients and *P* values between During, Post 1, Post 2, Post 3 and Post 4 for the behaviours: a) Back leg forward; b) Tremble; c) Back arch; and d) Paw

<b>a) Back leg forward</b>	Farrowing	Post 1	Post 2	Post 3
Post 1	0.412, 0.01**			
Post 2	0.318, 0.03**	0.492, 0.003**		
Post 3	0.195, 0.088	0.564, 0.001***	0.656, 0.001***	
Post 4	0.198, 0.085	0.612, 0.001***	0.500, 0.003**	0.755, 0.001***
<b>b) Tremble</b>	Farrowing	Post 1	Post 2	Post 3
Post 1	0.314, 0.032**			
Post 2	0.289, 0.040**	0.499, 0.003**		
Post 3	0.456, 0.005**	0.543, 0.001***	0.412, 0.010**	
Post 4	0.263, 0.051	0.432, 0.008**	0.451, 0.006**	0.722, 0.001***
<b>c) Back arch</b>	Farrowing	Post 1	Post 2	Post 3
Post 1	0.387, 0.014**			
Post 2	0.303, 0.035**	0.286, 0.041**		
Post 3	0.425, 0.009**	-0.099, 0.159	0.331, 0.027**	
Post 4	0.443, 0.007**	0.203, 0.083	0.24, 0.062	0.179, 0.098
<b>d) Paw</b>	Farrowing	Post 1	Post 2	Post 3
Post 1	0.418, 0.009**			
Post 2	0.389, 0.014**	0.096, 0.162		
Post 3	0.478, 0.004**	0.400, 0.012**	0.204, 0.082	
Post 4	-0.043, 0.209	0.007, 0.243	0.087, 0.170	0.254, 0.055

\*\*  $P < 0.05$ , \*\*\*  $P < 0.001$